MRSA Research Studies, Research-Based Reports, and Media Articles

NOTE: After each study, the country in which the research examined the occurrence of MRSA is identified in **boldface**. The affiliation of the lead researcher (collaborative work may involve professors from other universities as well as well as researchers from government agencies or institutes) is identified as well. All studies were published in peer-reviewed scholarly journals, thus meeting the highest possible research standards.

The **268** research studies, **34** research-based reports by government agencies, by independent, non-industrial organizations, or by university researchers, and the **30** media articles contained within this bibliography focus on seven lines of inquiry:

Research Reports **p. 1**

- Detection of MRSA in livestock, particularly swine; **35** p. 1
- Links between human exposure to pigs and human MRSA colonization/infection; **92** p. 6
- MRSA in meat products; **12** p. 17
- Impact of pig manure slurry applications to agricultural fields on microbial soil organisms, on soil, and on groundwater; **53** p. 18
- Spread of swine MRSA
  - to wildlife. **11** p. 24
  - through field applications of pig manure slurry. **10** p. 25
- Other antibiotic-resistant pathogens resulting from agricultural use of antibiotics; and **30** p. 26
- Risks posed by MRSA colonization. **25** p. 30

Research-based Reports **p. 33**

Media Articles **p. 37**

MRSA Research

Detection of MRSA in livestock, particularly swine

Agersø Y, Hasman H, Cavaco LM, Pedersen K, & Aarestrup FM (2012, May 25). Study of methicillin-resistant Staphylococcus aureus (MRSA) in Danish pigs at slaughter and in imported retail meat reveals a novel MRSA type in slaughter pigs. *Veterinary Microbiology, 157* (1-2): 246-250. Abstract retrieved February 16, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/22245403. **Denmark – Technical University of Denmark**

Agersø Y, Vigre H, Cavaco LM, & Josephsen MH (2014, August). Comparison of air samples, nasal swabs, ear-skin swabs and environmental dust samples for detection of methicillin-resistant Staphylococcus aureus (MRSA) in pig herds. *Epidemiology and Infection, 142* (8): 1727-1736. Abstract retrieved November 1, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/24229727. **Denmark – Technical University of Denmark**

Alt K, Fetsch A, Schroeter A, Guerra B, Hammerl JA, Hertwig S, Senkov N, Geinets A, Mueller-Graf C, Braeunig J, Kaesbohrer A, Appel B, Hensel A, & Tenhagen BA (2011, November 10). Factors associated with the occurrence of MRSA CC398 in herds of fattening pigs in Germany. *BMC Veterinary Research, 7*: 69. **Germany – Federal Institute for Risk Assessment**

Battisti A, Franco A, Merialdi G, Hasman H, Iurescia M, Lorenzetti R, Feltrin F, Zini M, & Aarestrup FM (2010, May 19). Heterogeneity among methicillin-resistant Staphylococcus aureus from Italian finished pig holdings. *Veterinary Microbiology, 142* (3-4): 361-366. Abstract retrieved February 16, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/19914010. **Italy – Istituto Zooprofilattico Sperimentale delle Regioni Lazio e Toscana**

Broens EM, Espinosa-Gongora C, Graat EA, Vendrig N, Van Der Wolf PJ, Guardabassi L, Butaye P, Nielsen JP, De Jong MC, & Van De Giessen AW (2012, May 18). Longitudinal study on transmission of MRSA CC398 within pig herds. *BMC Veterinary Research, 8*: 58. **The Netherlands – Quantitative Veterinary Epidemiology Group, Wageningen Institute of Animal Sciences, Wageningen University**

Broens EM, Graat EA, Van der Wolf PJ, Van de Giessen AW, & De Jong MC (2011, October 1). Prevalence and risk-factor analysis of livestock associated MRSA-positive pig herds in The Netherlands. *Preventive Veterinary Medicine, 102* (1): 41-49. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/21733585. **The Netherlands – Quantitative Veterinary Epidemiology Group, Wageningen Institute of Animal Sciences, Wageningen University**

Broens EM, Graat EA, Van der Wolf PJ, Van de Giessen AW, van Duijkeren E, & Wagenaar JA (2011, February 1). MRSA CC398 in the pig production chain. *Preventive Veterinary Medicine, 98* (2-3): 182-189. Abstract retrieved October 29, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/21075466. **The Netherlands – Quantitative Veterinary Epidemiology Group, Wageningen Institute of Animal Sciences, Wageningen University**

Crombé F, Willems G, Dispas M, Hallin M, Denis O, Suetens C, Gordts B, Struelens M, & Butaye P (2012, April). Prevalence and antimicrobial susceptibility of methicillin-resistant Staphylococcus aureus among pigs in Belgium. *Microbial Drug Resistance, 18* (2): 125-131. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/22088147. **Belgium – CODA-SERVA-VAR**

Crombé F, Argudín MA, Vanderhaeghen W, Hermans K, Haesebrouck F, & Butaye P (2013, March 20). Transmission dynamics of methicillin-resistant Staphylococcus aureus in pigs. *Frontiers in Microbiology, 4*: 57. **Belgium – Ghent University**

de Neeling AJ, van den Broek MJ, Spalburg EC, van Santen-Verheuvel MG, Dam-Deisz WD, Boshuizen HC, van de Giessen AW, van Duijkeren E, & Huijsdens XW (2007, June 21). High prevalence of methicillin-resistant Staphylococcus aureus in pigs. *Veterinary Microbiology, 122* (3-4): 366-372. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/17367960. **The Netherlands – National Institute for Public Health and the Environment**

Deurenberg RH, Vink C, Kalenic S, Friedrich AW, Bruggeman CA, & Stobberingh EE (2007, March). The molecular evolution of methicillin-resistant Staphylococcus aureus. *Clinical Microbiology and Infection, 13* (3): 322-335. **The Netherlands – University Hospital Maastricht**

Dressler AE, Scheibel RP, Wardyn S, Harper AL, Hanson BM, Kroeger JS, Dickema DJ, Bender JB, Gray GC, & Smith TC (2012, May 12). Prevalence, antibiotic resistance and molecular characterisation of Staphylococcus aureus in pigs at agricultural fairs in the USA. *The Veterinary Record, 170* (19): 495. **USA – University of Iowa**

Enright MC, Robinson DA, Randle G, Feil EJ, Grundmann H, & Spratt BG (2002, May 28). The evolutionary history of methicillin-resistant Staphylococcus aureus (MRSA). *Proceedings of the National Academy of Sciences of the United States of America, 99* (11): 7687-7692. **United Kingdom – University of Bath**

Espinosa-Gongora C, Broens EM, Moodley A, Nielsen JP, & Guardabassi L (2012, June 2). Transmission of MRSA CC398 strains between pig farms related by trade of animals. *The Veterinary Record, 170* (22): 564. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/22562100. **Denmark–University of Copenhagen**

Gómez-Sanz E, Torres C, Lozano C, Fernández-Pérez R, Aspiroz C, Ruiz-Larrea F, & Zarazaga M (2010, October). Detection, molecular characterization, and clonal diversity of methicillin-resistant Staphylococcus aureus CC398 and CC97 in Spanish slaughter pigs of different age groups. *Foodborne Pathogens and Disease, 7* (10): 1269-1277. Abstract retrieved February 16, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/20677918. **Spain – Universidad de La Rioja**

Harper AL, Ferguson DD, Leedom Larson KR, Hanson BM, Male MJ, Donham KJ, & Smith TC (2010). An overview of livestock-associated MRSA in agriculture. *Journal of Agromedicine, 15*: 101-104. **USA – University of Iowa**

Kadlec K, Ehricht R, Monecke S, Steinacker U, Kaspar H, Mankertz J, & Schwarz S (2009, December). Diversity of antimicrobial resistance pheno- and genotypes of methicillin-resistant Staphylococcus aureus ST398 from diseased swine. *The Journal of Antimicrobial Chemotherapy, 64* (6): 1156-1164. **Germany – Institute of Farm Animal Genetics**

Kehrenberg C, Cuny C, Strommenger B, Schwarz S, & Witte W (2009, February). Methicillin-resistant and –susceptible Staphylococcus aureus strains of clonal lineages ST398 and ST9 from swine carry the multidrug resistance gene cfr. *Antimicrobial Agents and Chemotherapy, 53* (2): 779-781. **Germany – Institute of Farm Animal Genetics**

Molla B, Byrne M, Abley M, Mathews J, Jackson CR, Fedorka-Cray P, Sreevatsan S, Wang P, & Gebreyes WA (2012, November). Epidemiology and genotypic characteristics of methicillin-resistant Staphylococcus aureus strains of porcine origin. *Journal of Clinical Microbiology, 50* (11): 3687-3693. Abstract retrieved February 16, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/22972820. **USA – Ohio State University**

Nicholson TL, Shore SM, Smith TC, & Frana TS (2013, August 9). Livestock-associated methicillin-resistant Staphylococcus aureus (LA-MRSA) isolates of swine origin form robust biofilms. *PLoS One, 8* (8): e73376. **USA – National Animal Disease Center (Ames), Iowa State University, & University of Iowa**

Overesch G, Büttner S, Rossano A, & Perreten V (2011, June 24). The increase of methicillin-resistant Staphylococcus aureus (MRSA) and the presence of an unusual sequence type ST49 in slaughter pigs in Switzerland. *BMC Veterinary Research, 7*: 30. **Switzerland – University of Bern**

Price LB, Stegger M, Hasman H, Aziz M, Larsen J, Andersen PS, Pearson T, Waters AE, Foster JT, Schupp J, Gillece J, Driebe E, Liu CM, Springer B, Zdovc I, Battisti A, Franco A, Zmudzki J, Schwarz S, Butaye P, Jouy E, Pomba C, Porrero MC, Ruimy R, Smith TC, Robinson DA, Weese JS, Arriola CS, Yu F, Laurent F, Keim P, Skov R, & Aarestrup FM (2012, February 21). Staphylococcus aureus CC398: Host adaptation and emergence of methicillin resistance in livestock. *mBio, 3* (1): e00305-e00311. **USA – Translational Genomics Research Institute**

Quitoco IM, Ramundo MS, Silva-Carvalho MC, Souza RR, Beltrame CO, de Oliveira TF, Araújo R, Del Peloso PF, Coelho LR, & Figueiredo AM (2013, August 27). First report in South America of companion animal colonization by the USA1100 clone of community-acquired methicillin-resistant Staphylococcus aureus (ST30) and by the European clone of methicillin-resistant Staphylococcus pseudintermedius (ST71). *BMC Research Notes, 6*: 336. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/23981343. **Brazil – Universidade Federal do Rio de Janeiro**

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Vanderhaeghen W, Hermans K, Haesebrouck F, & Butaye P (2010, May). Methicillin-resistant Staphylococcus aureus (MRSA) in food production animals. *Epidemiology and Infection, 138* (5): 606-625. Abstract retrieved February 16, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/19608357. **Belgium – Operational Directorate of Bacterial Diseases, Veterinary and Agrochemical Research Centre**

van de Vijver LP, Tulinski P, Bondt N, Mevius D, & Verwer C (2014, August). Prevalence and molecular characteristics of methicillin-resistant Staphylococcus aureus (MRSA) in organic pig herds in The Netherlands. *Zoonoses and Public Health, 61* (5): 338-345. Abstract retrieved October 29 2014, from http://www.ncbi.nlm.nih.gov/pubmed/24751151. **The Netherlands – Department of Nutrition and Health, Louis Bolk Institute**

van Duijkeren E, Ikawaty R, Broekhuizen-Stins MJ, Jansen MD, Spalburg EC, de Neeling AJ, Allaart JG, van Nes A, Wagenaar JA, & Fluit AC (2008, January 25). Transmission of methicillin-resistant Staphylococcus aureus strains between different kinds of pig farms. *Veterinary Microbiology, 126* (4): 383-389. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/17765409. **The Netherlands – Utrecht University**

Verhegghe M, Crombé F, Pletinckx LJ, Haesebrouck F, Butaye P, Herman L, Heyndrickx M, & Rasschaert G (2014, September 13). Genetic diversity of livestock-associated MRSA isolates obtained from piglets from farrowing to slaughter age on four farrow-to-finish farms. *Veterinary Research, 45* (1): 89. **Belgium – Food Safety Research Group, Institute for Agricultural and Fisheries Research**

Verhegghe M, Pletinckx LJ, Crombé F, Vandersmissen T, Haesebrouck F, Butaye P, Heyndrickx M, & Rasschaert G (2013, August). Methicillin-resistant Staphylococcus aureus (MRSA) ST398 in pig farms and multispecies farms. *Zoonoses and Public Health, 60* (5): 366-374. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/22925210. **Belgium – Food Safety Research Group, Institute for Agricultural and Fisheries Research**

Voss A, Loeffen F, Bakker J, Klaassen C, & Wulf M (2005, December). Methicillin-resistant Staphylococcus aureus in pig farming. *Emerging Infectious Diseases, 11* (12): 1965-1966. **The Netherlands – Radboud University Medical Centre**

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Weese JS (2010). Methicillin-resistant Staphylococcus aureus in animals. *ILAR Journal [National Research Council, Institute of Laboratory Animal Resources], 51* (3): 233-244. **Canada – University of Guelph**

Zhu Y-G, Johnson TA, Su J-Q, Qiao M, Guo G-X, Stedtfeld RD, Hashsham SA, & Tiedje JM (2013, February 26). Diverse and abundant antibiotic resistance genes in Chinese swine

farms. *Proceedings of the National Academy of Sciences of the United States of America, 110* (9): 3435-3440. **China – Chinese Academy of Sciences; USA – Center for Microbial Ecology, Michigan State University**

Links Between Human Exposure to Pigs and Human MRSA Colonization / Infection

Ahmad A, Ghosh A, Schal C & Zurek L (2011, January 26). Insects in confined swine operations carry a large antibiotic resistant and potentially virulent enterococcal community. *BMC Microbiology, 11* (1): 23. **USA – Kansas State University**

Alvarado CS, Gibbs SG, Gandara A, Flores C, Hurd WW, & Green CF (20122, March). The potential for community exposures to pathogens from an urban dairy. *Journal of Environmental Health, 74* (7): 22-28. Abstract retrieved October 24, 2012, from http://www.ncbi.nlm.nih.gov/pubmed/?term=MRSA+and+CAFO. **USA – University of Texas**

Armand-Lefevre L, Ruimy R, & Andremont A (2005, May). Clonal comparison of Staphylococcus aureus isolates from healthy pig farmers, human controls and pigs. *Emerging Infectious Diseases, 11* (5): 711-714. **France – Groupe Hospitalier Bichat-Claude Bernard**

Ballhausen B, Jung P, Kriegeskorte A, Makgotlho PE, Ruffing U, von Müller L, Köck R, Peters G, Herrmann M, Ziebuhr W, Becker K, & Bischoff M (2014, October). LA-MRSA, CC398 differ from classical community acquired-MRSA and hospital acquired-MRSA lineages: Functional analysis of infection and colonization processes. *International Journal of Medical Microbiology, 304* (7): 777-786. Abstract retrieved November 15, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/25034858. **Germany – Institute of Medical Microbiology, University Hospital of Münster**

Bisdorff B, Scholhölter JL, Claußen K, Pulz M, Nowak D, & Radon K (2012 October). MRSA-ST398 in livestock farmers and neighbouring residents in a rural area in Germany. *Epidemiology and Infection, 140* (10): 1800-1808. Abstract retrieved September 25, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/?term=MRSA-ST398+in+livestock+farmers+and+neighbouring+residents+in+a+rural+area+in+Germany. **Germany – University Hospital of Munich**

Bootsma MC, Wassenberg MW, Trapman P, & Bonten MJ (2011, April 6). The nosocomial transmission rate of animal-associated ST398 meticillin-resistant [sic] Staphylococcus aureus. *The Journal of the Royal Society, Interface, 8* (57): 578-584. **The Netherlands – Utrecht University**

Carrel M, Schweizer ML, Sarrazin MV, Smith TC, & Perencevich EN (2014, February). Residential proximity to large numbers of swine in feeding operations is associated with increased risk of methicillin-resistant Staphylococcus aureus colonization at time of hospital admission in rural Iowa veterans. *Infection Control and Hospital Epidemiology, 35* (2): 190-193. **USA – University of Iowa**

Cui S, Li J, Hu C, Jin S, Li F, Guo Y, Ran L, & Ma Y (2009, October). Isolation and characterization of methicillin-resistant Staphylococcus aureus from swine and workers in China. *Journal of Antimicrobial Chemotherapy, 64* (4): 680-683. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/19684078. **China – The State Food and Drug Administration**

Cuny C, Friedrich AW, & Witte W (2012, February). Absence of livestock-associated methicillin-resistant Staphylococcus aureus clonal complex CC398 as a nasal colonizer of pigs raised in an alternative setting. *Applied and Environmental Microbiology, 78* (4): 1296-1297. **Germany – Robert Koch Institute**

Cuny C, Köck R, & Witte W (2013, August). Livestock-associated MRSA (LA-MRSA) and its relevance for humans in Germany. *International Journal of Medical Microbiology, 303* (6-7): 331-337. Abstract retrieved October 29, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/23607972. **Germany – Robert Koch Institute**

Cuny C, Nathaus R, Layer F, Strommenger B, Altmann D, & Witte W (2009, August). Nasal colonization of humans with methicillin-resistant Staphylococcus aureus (MRSA) CC398 with and without exposure to pigs. *PLoS One, 4* (8): e6800. **Germany – Robert Koch Institute**

Dahms C, Hübner NO, Cuny C, & Kramer A (2014, August 21). Occurrence of methicillin-resistant Staphylococcus aureus in farm workers and the livestock environment in Mecklenburg-Western Pomerania, Germany. *Acta Veterinaria Scandinavica, 56*: 63. **Germany – University Medicine Greifswald, Institute of Hygiene and Environmental Medicine**

Dahms C, Hübner NO, Wilke F, & Kramer A (2014, September 30). Mini-review: Epidemiology and zoonotic potential of multiresistant bacteria and Chlostridium difficile in livestock and food. *GMS Hygiene and Infection Control, 9* (3): Doc21. **Germany – University Medicine Greifswald, Institute of Hygiene and Environmental Medicine**

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Dukic VM, Lauderdale DS, Wilder J, Daum RS, & David MZ (2013, January). Epidemics of community-associated methicillin-resistant Staphylococcus aureus in the United States: A meta-analysis. *PLoS One, 8* (1): e52722 **USA – University of Colorado**

Espinosa-Gongora C, Moodley A, Lipinska U, Broens EM, Hermans K, Butaye P, Devriese LA, Haesebrouck F, & Guardabassi L (2014, July 7). Phenotypes and genotypes of old and contemporary porcine strains indicate a temporal change in the S. aureus population structure in pigs. *PLoS One, 9* (7): e101988. **Denmark–Department of Veterinary Disease Biology, Faculty of Health and Medical Sciences, University of Copenhagen**

Fang HW, Chiang PH, & Huang YC (2014, February 13). Livestock-associated methicillin-resistant Staphylococcus aureus ST9 in pigs and related personnel in Taiwan. *PLoS One,*

9 (2): e88826. Abstract retrieved March 2, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/24551168. **Taiwan – Chang Gung University**

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Frana TS, Beahm AR, Hanson BM, Kinyon JM, Layman LL, Karriker LA, Ramirez A, & Smith TC (2013). Isolation and characterization of methicillin-resistant Staphylococcus aureus from pork farms and visiting veterinary students. *PLoS One, 8* (1): e53758. **USA – Iowa State University**

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Gibbs SG, Green CF, Tarwater PM, & Scarpino PV (2004, November). Airborne antibiotic resistant and nonresistant bacteria and fungi recovered from two swine herd confined animal feeding operations. *Journal of Occupational and Environmental Hygiene, 1* (11): 699-706. **USA – University of Texas**

Gibbs SG, Green CF, Tarwater PM, Mota LC, Mena KD, & Scarpino PV (2006, July). Isolation of antibiotic-resistant bacteria from the air plume downwind of a swine-confined or concentrated animal feeding operation. *Environmental Health Perspectives, 114* (7): 1032-1037. **USA – University of Texas**

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Harrison EM, Paterson GK, Holden MT, Larsen J, Stegger M, Larsen AR, Petersen A, Skov RL, Christensen JM, Bak Zeuthen A, Heltberg O, Harris SR, Zadoks RN, Parkhill J, Peacock SJ, & Holmes MA (2013, April). Whole genome sequencing identifies zoonotic transmission of MRSA isolates with the novel mecA homologue mecC. *EMBO Molecular Medicine, 5* (4): 509-515. **United Kingdom – Department of Veterinary Medicine, Cambridge University**

Hartmeyer GN, Gahrn-Hansen B, Skov RL, & Kolmos HJ (2010, April). Pig-associated methicillin-resistant Staphylococcus: Family transmission and severe pneumonia in a newborn. *Scandinavian Journal of Infectious Diseases, 42* (4): 318-320. Abstract retrieved November 18, 2014, from http://www.ncbi.nlm.nih.gov/pubmed/20121648. **Denmark – Department of Clinical Microbiology, Odense University Hospital**

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Huang E, Gurzau AE, Hanson BM, Kates AE, Smith TC, Pettigrew MM, Spinu M, & Rabinowitz PM (2014, July-August). Detection of livestock-associated methicillin-resistant Staphylococcus aureus among swine workers in Romania. *Journal of Infection and Public Health, 7* (4): 323-332. Abstract retrieved September 22, 2014 from http://www.ncbi.nlm.nih.gov/pubmed/24821273. **USA – Yale University**

Huijsdens XW, van Dijke BJ, Spalburg E, van Santen-Verheuvel MG, Heck ME, Pluister GN, Voss A, Wannet WJ, & de Neeling AJ (2006, November 10). Community-acquired MRSA and pig-farming. *Annals of Clinical Microbiology and antimicrobials, 5*: 26. **The Netherlands – National Institute for Public Health and the Environment**

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